



Affordable Zero Energy K-12 Schools: The Cost Barrier Illusion

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Cover photo: Jennings Creek Elementary, a zero energy school in Bowling Green, Kentucky, cost \$1.5 million less to build than the average Kentucky school and saves more than \$195,000 a year in energy costs compared to a conventional school.

Photo from Sherman Carter Barnhart Architects, Chris Phebus Photography

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The budget for Discovery Elementary School, a zero energy school in Arlington, Virginia, was fixed from the outset, and the innovative architectural and engineering team completed the project—including the solar photovoltaic system—for less money than the district had allocated.

Photo from VMDO Architects, Alan Karchmer Photography

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TABLE OF CONTENTS

ACKNOWLEDGMENTS.....	4
INTRODUCTION.....	6
Background.....	7
Schools Take the Lead.....	7
RESEARCH RESULTS.....	10
The Research.....	11
The Results.....	11
Key Takeaways.....	14
COST CONTROL.....	16
Establishing a Budget and Energy Goal.....	17
Shifting Costs.....	18
Choosing a Procurement Process.....	18
Measuring and Verifying Performance.....	19
BENEFITS AND CHALLENGES.....	20
Benefits.....	21
School Districts.....	21
Students and Staff.....	21
Communities.....	21
Challenges.....	22
Risk Management.....	22
School Governance and Funding.....	22
CASE STUDIES.....	23
Small Decisions, Big Benefits:	
Warren County Public Schools.....	24
RICHARDSVILLE ELEMENTARY SCHOOL	
PROJECT DETAILS.....	26
JENNINGS CREEK ELEMENTARY SCHOOL	
PROJECT DETAILS.....	27
Robust, Affordable K–12 Education:	
Arlington Public Schools.....	28
DISCOVERY ELEMENTARY SCHOOL PROJECT DETAILS.....	29
A Path to Energy Positive: Horry County Schools.....	30
ST. JAMES INTERMEDIATE SCHOOL PROJECT DETAILS.....	31
CONCLUSIONS.....	32
ACRONYMS.....	34
GLOSSARY.....	34
APPENDIX A: ZERO ENERGY SCHOOLS	
ACCELERATOR.....	35



INTRODUCTION

Jennings Creek Elementary School in Bowling Green, Kentucky, was designed to operate at an energy use intensity of 17.5 kBtu/ft²-yr, but it has exceeded expectations and is operating at 15.5 kBtu/ft²-yr.

Photo from Sherman Carter Barnhart Architects, Chris Phebus Photography

Despite the many examples of zero energy (ZE) schools built at costs comparable to or less than conventional schools, the perception persists that ZE schools cost more. Evaluating this belief is important because the perception of risk alone can drive up costs (see **Risk Management, page 22**).

The pressures to contain costs in school design and construction can be intense, and—because many stakeholders still cite cost as a major barrier to designing and building a ZE K–12 school—those pressures can thwart efforts to pursue a ZE or zero energy ready (ZER) project. By examining the costs of a subset of existing ZE schools and the strategies used to contain those costs, architects, engineers, owners, and researchers are challenging the notion that cost is a barrier to building ZE schools.

As one architect who has designed multiple ZE schools put it, “The people who say zero energy is unaffordable or unfeasible are usually those who have never done it.”

Background

Interest in very low energy buildings is growing across the United States. California, for example, has adopted ZE targets for 50% of the floor area of existing state-owned buildings by 2025 and for all new or renovated state buildings beginning design after 2025.¹ California has also set a target of making all new commercial buildings ZE by 2030.² Several other states are considering similar measures and have established task forces to work on the issue.

A ZE building produces as much energy—usually with solar photovoltaics (PV)—as it consumes on an annual basis.³ ZER buildings are designed and built to accept an on-site renewable energy system, but the installation is postponed for budgetary or other reasons. The number of ZE and ZER buildings in the United States is increasing as the process of getting to ZE is refined and simplified by forward-thinking building owners, communities, and design and building professionals.

Advances in technology and integrated design together with sharp reductions in the cost of renewable energy make ZE feasible⁴ and affordable now. These trends are

corroborated by a dramatic increase in the number of documented ZE buildings.⁵

As one architect who has designed multiple ZE schools put it, “The people who say zero energy is unaffordable or unfeasible are usually those who have never done it.”

Schools Take the Lead

K–12 schools are leading the market shift from buildings that consume energy to buildings that produce as much renewable energy as they use. School buildings often reflect the larger community’s ideals of fiscal responsibility, educational innovation, and environmental stewardship, and successful ZE schools provide a collection of compelling case studies with measured energy performance data.

For example, a team of school design experts and owners supported by energy modeling simulations from the National Renewable Energy Laboratory assembled the *Advanced Energy Design Guide for K–12 School Buildings: Achieving Zero Energy* (ZE K12 AEDG), which was published in 2018.⁶ This free, downloadable guide provides a set of energy use intensities (EUIs, a measure of energy consumption expressed in thousands of British thermal units per square foot per year [kBtu/ft²·yr]) for K–12 buildings, practical guidance for achieving those EUIs, and a sample of schools that have achieved the targets. Schools that meet these EUI criteria but postpone installing a renewable energy system are considered ZER.⁷

In addition, as part of the U.S. Department of Energy’s Zero Energy Schools Accelerator,⁸ the National Renewable Energy Laboratory published *A Guide to Zero Energy*

1 https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.31.pdf

2 <https://www.energy.ca.gov/programs-and-topics/programs/energy-efficiency-existing-buildings>

3 https://www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf, <https://youtu.be/FysJKq5yCfQ>

4 <https://www.nrel.gov/docs/fy17osti/67233.pdf>

5 <https://newbuildings.org/resource/2020-getting-to-zero-project-list>

6 <https://www.ashrae.org/aedg>

7 <https://zeroenergy.org/about/>

8 <https://zeroenergy.org/project-types/schools/zero-energy-schools-accelerator/>

and Zero Energy Ready K–12 Schools⁹ with editorial content support from school districts, nongovernmental organizations, and ZE design and construction professionals. The free, downloadable document is organized into eight steps:

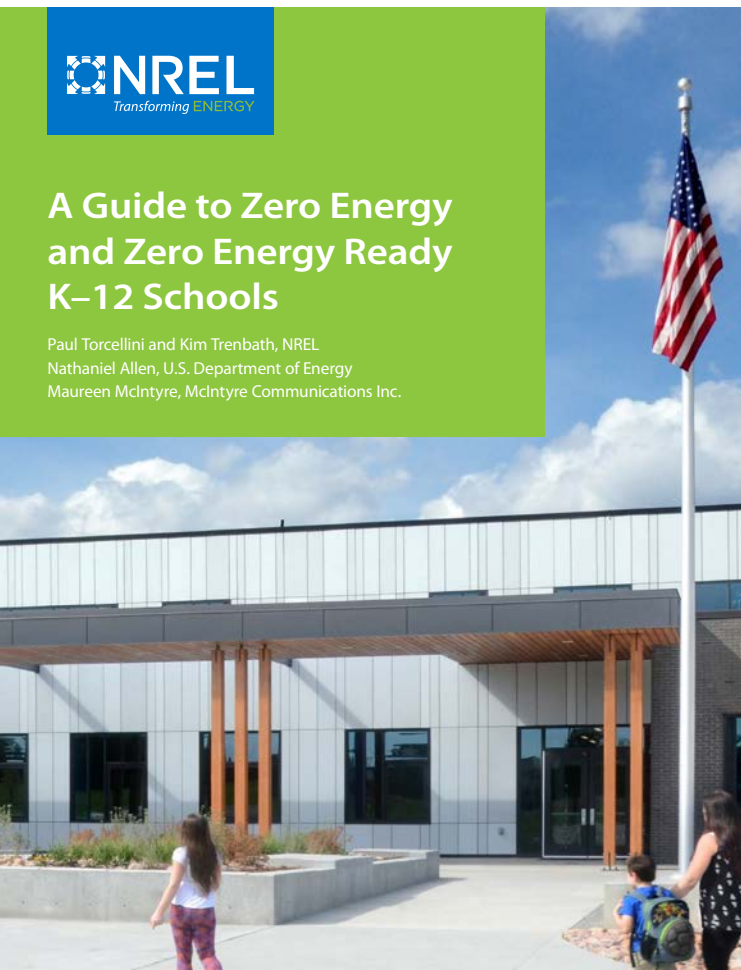
1. Conducting a building needs assessment
2. Engaging stakeholders
3. Including ZE goals in the procurement process
4. Selecting a design and construction team committed to ZE goals
5. Integrating ZE goals into design
6. Achieving ZE goals during construction and commissioning
7. Evaluating performance and engaging occupants
8. Showcasing and replicating a ZE school.

Each step contains a short anecdote from a school district offering a quick synopsis of that district's experience with the step as well as a list of relevant resources. More technical sources can be found in a reference list at the end of the publication.

There are now enough ZE schools operating that there is less risk associated with tackling a ZE project. Design firms that commit to ZE can, however, expect to invest in educating staff and clients, improving modeling capabilities, and identifying and adopting cost control strategies.

There are now enough ZE schools operating that there is less risk associated with tackling a ZE project.

The process is analogous to the switch to computer-aided design (CAD) by architectural and engineering firms. As that transition demonstrated, once a methodology or technological advance gains traction in the market, transformation can happen quickly. The first architectural drawing software for use on personal computers was released in 1982. Within 20 years of that release, most companies had invested in information technology staff and infrastructure to learn about and shift to the new technology. Today, there are dozens of architectural drawing software options and firms invest in the technology and trained staff to remain relevant and competitive.



⁹ <https://www.nrel.gov/docs/fy19osti/72847.pdf>

Similarly, ZE is a way of thinking about whole-building energy performance as well as a methodology for achieving specific energy targets in buildings. Just as design teams had to change workflows to adapt to CAD, achieving ZE may require modifying design and delivery processes. Making ZE standard practice is a paradigm shift for most school districts and building professionals, but owners and project teams can use the lessons learned from existing ZE projects as guides to develop their own cost-effective ZE schools (see **CASE STUDIES**, page 23). The growing number of ZE schools demonstrates that when owners and project teams adopt ZE goals and cost control strategies early in the process, costs can be comparable to or even less than conventional schools (see **Small Decisions, Big Benefits: Warren County Public Schools**, page 24, and **Robust, Affordable K–12 Education: Arlington Public Schools**, page 28).

ZE is a way of thinking about whole-building energy performance as well as a methodology for achieving specific energy targets in buildings.



Zero energy can enhance students' educational experience. In 2017, Mr. Brandt's kindergarten class at Graceland Park/O'Donnell Heights Elementary/Middle School in the inner city of Baltimore built a model of their new zero energy school with graham crackers and chocolate bars. The school opened in September 2020.

Photos from Grimm + Parker Architects



RESEARCH RESULTS

Jennings Creek Elementary in Bowling Green, Kentucky, is the first zero energy school funded by a guaranteed energy savings contract. The agreement is between Warren County Public Schools and CMTA Energy Solutions and, over time, will finance, replace, and upgrade energy systems through project savings district-wide.

Photo from Sherman Carter Barnhart Architects,
Chris Phebus Photography

Evaluating the belief that ZE schools are more expensive than conventional schools is important because the perception of risk alone can drive up costs (see **Risk Management, page 22**). Toward that end, researchers collected project cost, energy performance, and other data on approximately 150 K–12 schools around the United States.

The Research

Most of the information came from presentations; public records; design firm websites; and personal communications with architects, engineers, school district personnel, and partners in the U.S. Department of Energy's Zero Energy Schools Accelerator.¹ The cost data have limitations in that different schools can have different boundary conditions. For most schools, land acquisition is not included in the project costs of the school; however, other items such as site infrastructure, school district administrative costs, and furniture may or may not be included in the reported project costs.

Although data were collected on school renovations that resulted in a substantial reduction in energy use, the focus for this analysis was on new construction. The many differences between renovations and renovations plus additions make comparisons difficult.

The data were normalized to average 2019 costs (last available) and to a fictitious location that represents the “average” construction cost location. When they were

available, cost data were as of the bid date. If the bid date was not known, the occupancy date minus 2 years was used to establish the cost basis. Note that the year cost basis is a yearly value so a school that is occupied for August would have a construction time of between 20 and 32 months. The original group of roughly 150 U.S. schools was narrowed to 88 schools for which data on costs, projected or measured EUI, and location were available.

The Results

The school buildings included in **Figure 1** are drawn from multiple sources, and were selected based on the availability of information. In addition, some of the EUIs are higher than the target EUI values established for ZER schools in the ZE K12 AEDG.² **Figure 1** shows the distribution of schools operating at EUIs of less than 30 kBtu/ft²·yr and, although that is higher than the AEDG recommendations, it represents a significant savings compared with current energy standards. ZE and ZER schools have been built in urban and rural areas as well as in a variety of climate zones.

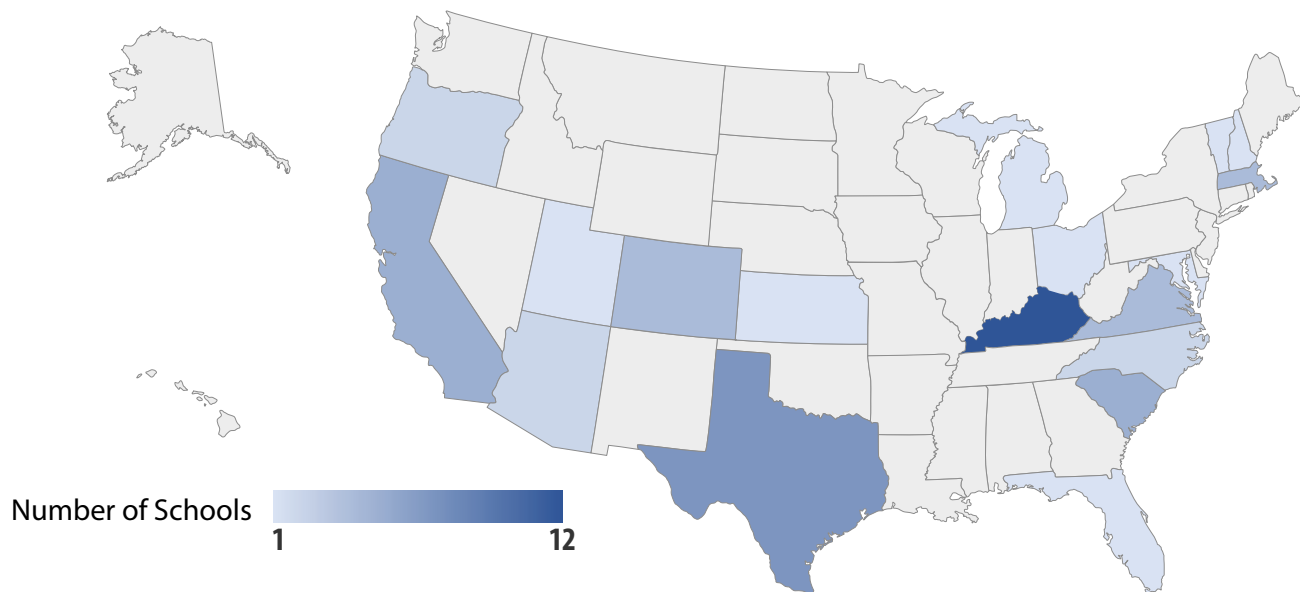


Figure 1. The geographic distribution of the schools with energy use intensities less than or equal to 30 kBtu/ft²·yr

¹ <https://betterbuildingssolutioncenter.energy.gov/accelerators/zero-energy-schools>

2 <https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download>

In **Figure 2**, the bubble sizes represent school size, with larger bubbles representing larger schools. The project cost data were plotted versus the EUI of the school. The orange line is the average cost of schools as reported in the *State of Our Schools: America's K-12 Facilities 2016*³ report. Average costs range from \$205 to \$495 per ft² and there is a set of higher-priced outlier schools with EUIs in the 20 to 30 range. Some other outliers are very small projects, often one or two classroom buildings on a school campus. **Figure 2** includes schools in the sample set with EUIs of more than 30 kBtu/ft²·yr and demonstrates that school capital costs are independent of energy performance.

Many of the ZE schools are less expensive than an average school and fall within a tight cost range. For most of the schools in this analysis, project costs are independent of EUI. Most districts are under considerable pressure to keep school costs under control and the process is public and transparent. School districts respond to public pressure and sometimes have state requirements that mandate school costs. Like all schools, ZE schools must be responsive to these cost pressures. A ZE school can help alleviate school districts' economic pressures, as the ZE schools built for less than conventional schools demonstrate (see **CASE STUDIES**, page 23).

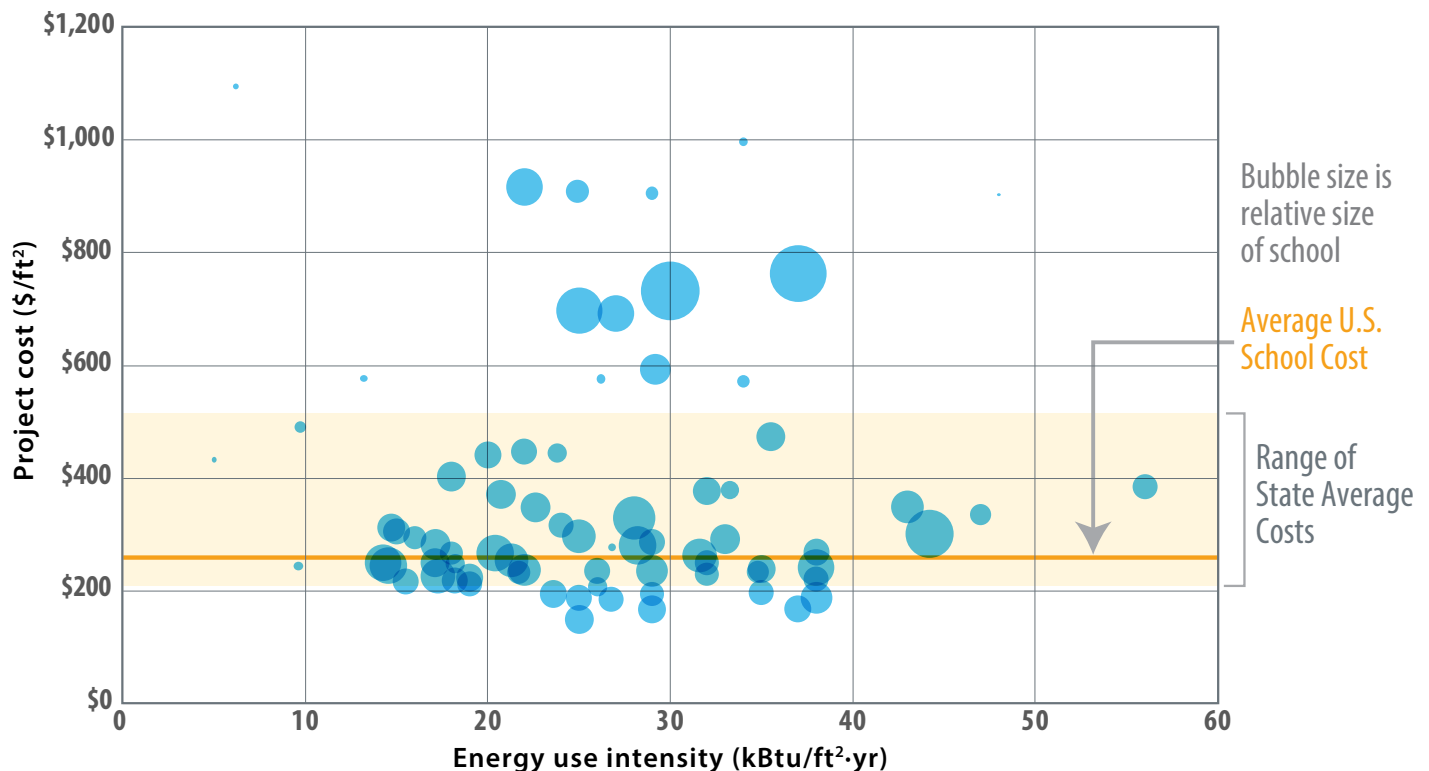


Figure 2. Graph of project cost and energy use intensity for the 88 K–12 schools studied

During the past 15 years, design strategies and building technologies have been refined to the point that school buildings can generate as much energy as they use with on-site renewable energy at costs comparable to or less than conventional schools. The energy efficiency progression is summarized in **Figure 3**.

The first *Advanced Energy Design Guide* (AEDG) for K–12 schools demonstrated ways to achieve a 30% energy savings compared with ASHRAE Standard 90.1-1999. When the guide was updated to a 50% energy reduction, the basis was ASHRAE 90.1-2004. The ZE K12 AEDG is different from the 30% and 50% guides in that it does not reference a baseline. Rather, in the ZE K12 AEDG guide, ZE is an absolute goal.

A ZE school can help alleviate school districts' economic pressures, as the ZE schools built for less than conventional schools demonstrate.

³ <https://kapost-files-prod.s3.amazonaws.com/published/56f02c3d626415b792000008/2016-state-of-our-schools-report.pdf?kui=wo7vkgV0wW0LGSJxek0N5A>

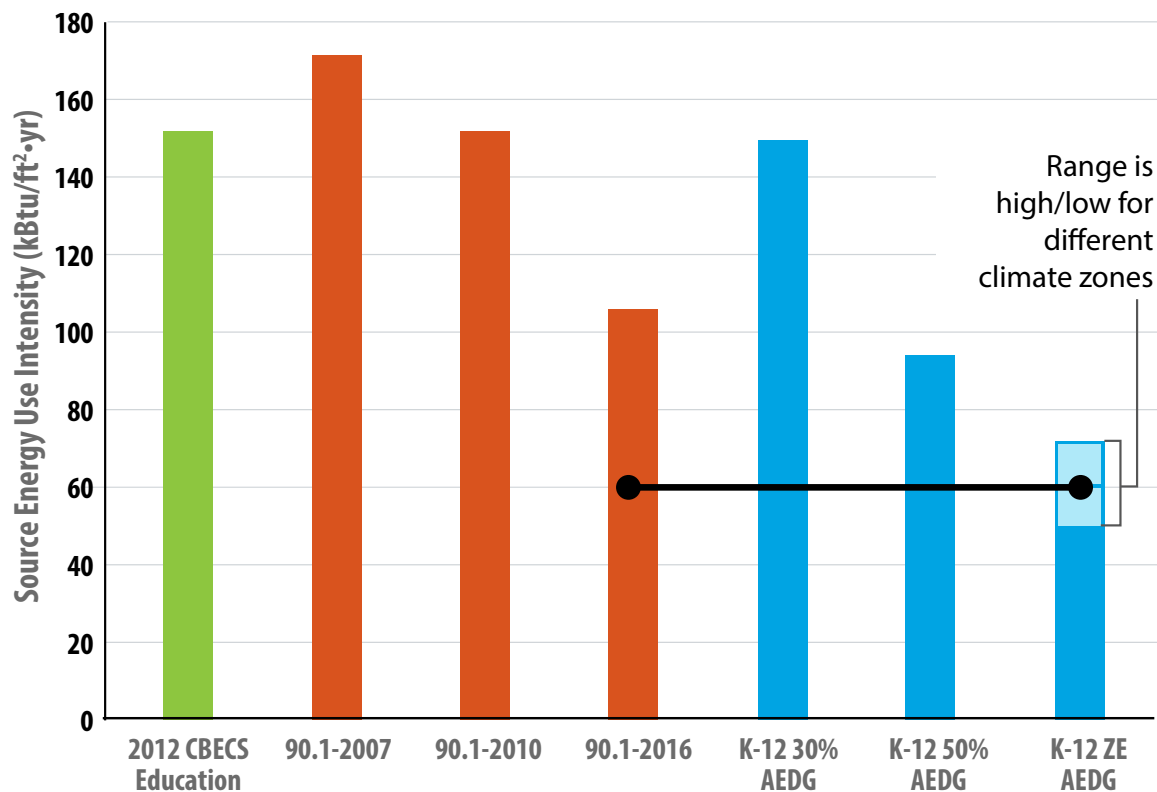


Figure 3. Comparison of U.S. average source energy use intensity data for K–12 schools compared to ASHRAE Standards and Advanced Energy Design Guides

The ZE K12 AEDG guide establishes EUI targets, however, and these targets are 42% better than ASHRAE 90.1-2016, which is a substantial improvement over ASHRAE 90.1-2010 as the black line in **Figure 3** indicates. As codes become more stringent, improvements in building performance are keeping pace as a result of continued innovation and technological advances; state-of-the-art-buildings continue to outperform building standards by 40%–50%.

Figure 4 includes the 52 projects (59% of the sample set) that have EUIs less than 30 kBtu/ft²·yr. Of these 52 schools, 71% have EUIs less than 25 kBtu/ft²·yr.

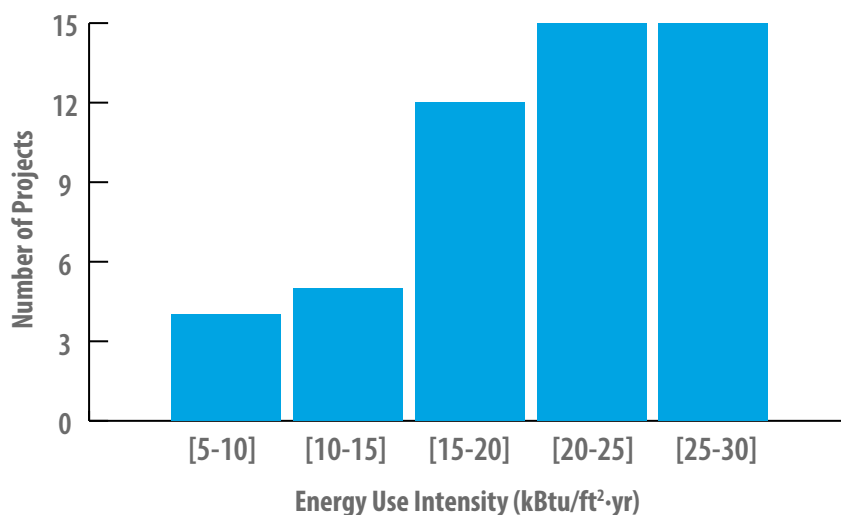


Figure 4. Site energy use intensities for the subset of K–12 schools in the sample set that have energy use intensities less than 30 kBtu/ft²·yr

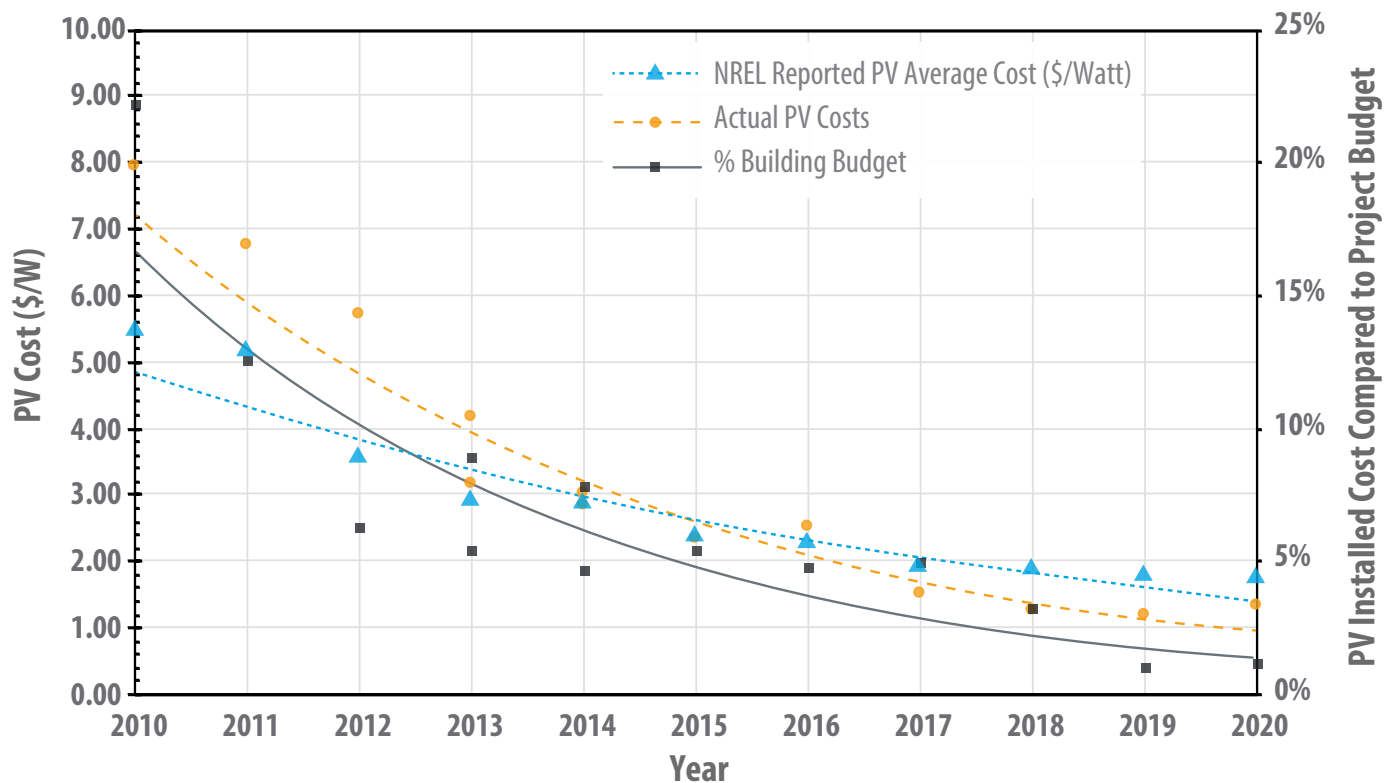


Figure 5. Cost of photovoltaics for actual projects compared with average photovoltaics costs for U.S. commercial buildings (200 kW average size) and the percentage of building budgets required for photovoltaics sufficient to achieve zero energy

For a select number of projects (see Figure 5), the incremental cost of PV as a percentage of the project cost was available. Before 2011, the incremental cost of providing enough PV to match building energy consumption was more than 7% of total project costs. As project EUIs dropped—reducing the size of the PV array—the cost of PV has also dropped. The result is that the percentage of the total building budget required for PV has decreased more quickly than the reduction in PV costs.

The incremental cost of adding PV to go from ZER to ZE is less than 3% for this collection of commercial buildings. This reduction in incremental cost can be attributed to design teams specifying PV early in the process and including infrastructure to easily incorporate the PV. It is also a result of dramatic PV cost reductions during the last decade.⁴

Now that the percent PV increases a building's budget is smaller than a typical 5% cost estimating error, PV can be routinely included in most building designs as an add-alternate. This allows for inclusion if funds are available through the construction bidding process. An add-alternate list includes amenities or features offered to owners

and the prices of those extras. Owners can then accept the features they prefer and can afford. If the bid comes in within the total ceiling, PV can easily be incorporated into the project.

Key Takeaways

The number of ZE schools designed and built on comparable or smaller budgets than local conventional schools is growing nationwide. Lessons learned from successful ZE school projects (see CASE STUDIES, page 23, for examples) include:

ZE and ZER schools are being built in a variety of U.S. climate zones and locations (see Figure 1, page 11). They are also being built in urban and rural communities.

ZE schools need not cost more than conventional schools. When they do, it is a result of added amenities rather than energy efficiency or renewable energy upgrades.

⁴ <https://www.nrel.gov/news/program/2021/documenting-a-decade-of-cost-declines-for-pv-systems.html>

ZE schools can cost less than conventional schools.

Energy efficiency improvements not only reduce ongoing operating costs but unlock synergies that reduce first costs (see *Shifting Costs*, page 18; *Small Decisions, Big Benefits: Warren County Public Schools*, page 24; *Robust, Affordable K–12 Education: Arlington Public Schools*, page 28).

The perception that ZE schools are expensive and risky alone can drive up costs.

Project team members unfamiliar with ZE building or unconvinced of its benefits are likely to increase bids to cover unforeseen expenses.

The cost of a school does not correlate with energy consumption (EUI).

This is confirmed by the scatter in the cost data (see *Figure 2*, page 12) and the lack of a link between cost and EUI as well as the instances of ZE schools that cost less than conventional schools in the same district (see *Small Decisions, Big Benefits: Warren County Public Schools*, page 24; *Robust, Affordable K–12 Education: Arlington Public Schools*, page 28).

Design teams are becoming increasingly adept at designing very energy-efficient buildings.

Skilled designers; improved energy efficiency technologies; and free, easily accessible design guidance⁵ (see *Figure 3*, page 13) could make ZE schools the rule rather than the exception.

⁵ <https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download>

A fixed budget and firm EUI established early in the process are key.

Setting a budget and an absolute EUI value—preferably in the low 20s or less—helps shift conversations from how much cost ZE will add to how to achieve ZE within the existing budget; these strategies can reveal energy and dollar savings that would otherwise be missed.

Many schools are currently operating with low EUIs.

In the sample data set for this report alone, more than half the schools have an EUI of less than 25 kBtu/ft²-yr.

PV is so inexpensive that it can routinely be added to new schools.

The cost of PV has dropped dramatically (see *Figure 5*, page 14) and the incremental cost of adding PV to a commercial building has fallen to less than 3% of the project budget in many cases.

ZE schools can relieve economic pressures on school districts.

Because they have reduced operating costs and often even reduced first costs, ZE schools improve districts' economic health.

Experienced ZE designers often prefer a performance-based design-build procurement process.

The design-build process defines the rules early and determines best value for the owner through a competitive process; successful ZE schools are not solely dependent on the delivery method, however (see *Robust, Affordable K–12 Education: Arlington Public Schools*, page 28).

The solar rooftop laboratory at Discovery Elementary School In Arlington, Virginia, is an example of how a zero energy school can enhance student learning.

Photo from VMDO Architects, Lincoln Barbour Photography





COST CONTROL

The zero energy bid for Discovery Elementary School in Arlington, Virginia, was \$1 million less than the initial budget, making it possible to add solar photovoltaics and achieve zero energy within the budget.

Photo from VMDO Architects, Alan Karchmer Photography

In conversations with architects, engineers, and school district officials working on ZE or ZER schools, innovations emerged that help contain up-front costs. The fact that ZE can dramatically reduce energy and operating costs over a building's lifetime is a key benefit, but architects and engineers report that most clients are more interested in first costs.¹

That can make redirecting owners' attention to life cycle or operating costs a hard sell, which puts pressure on project teams to reduce first costs as well as energy and life cycle costs. Fortunately, dramatic energy efficiency improvements such as those in ZE schools not only save energy and money but also unlock synergies that can reduce first costs (see **Shifting Costs**, page 18). Changing the conversation from "how much more will ZE cost" to "how can we achieve ZE within our budget" can reveal opportunities for energy and dollar savings that a more conventional approach would miss.

Project teams have developed and refined the strategies discussed here during the process of designing and building existing ZE schools. Adopting these approaches can keep costs in line with conventional schools and reduce the perception that ZE schools are untested and therefore risky to the design team, contractor, and school district. The perception of risk alone can drive up costs because project team members will often increase bids to limit exposure (see **Risk Management**, page 22).

Changing the conversation from "how much more will ZE cost" to "how can we achieve ZE within our budget" can reveal opportunities for energy and dollar savings that a more conventional approach would miss.

Establishing a Budget and Energy Goal

Establishing a fixed budget and setting an absolute EUI target at the outset of the project can take some of the uncertainty and attendant risk out of a ZE school project, especially for districts and project teams new to ZE and ZER buildings. Establishing an EUI goal is not standard practice for most building projects, even those characterized as "green" or "energy-efficient." Typically, an energy use projection is calculated after the design

is substantially complete, and energy performance is determined during the design process. In a ZE school project, however, energy performance drives the design process.

Establishing a fixed budget and setting an absolute EUI target at the outset of the project can take some of the uncertainty and risk out of a ZE school project.

Energy goals can be established and validated several ways. A good place to start is the ZE K12 AEDG.² In this publication, computer models combined with actual building case studies were used to create energy goals for a ZER school. To establish the target EUI:

- Use the recommended values from Table 3-1, page 34, in the ZE K12 AEDG and demonstrate to stakeholders that the EUI targets are attainable by providing case studies of similar schools that achieved low EUIs (see **CASE STUDIES**, page 23).
- Determine whether the school will have specialty functions and add these uses to the energy total; examples include swimming pools, ice rinks, television-quality lighting for sports fields, laboratories, technical education centers, and spaces with higher energy and ventilation requirements.
- Adjust the EUI goal down whenever possible to achieve higher efficiencies, which will reduce the size and cost of the on-site renewable generation required to meet the building's energy loads.

Any school can be ZE with a big enough PV system. Energy efficiency, however, reduces the size and cost of the renewable energy system, and provides benefits with or without solar, notably reduced operating costs (see **Benefits**, page 21).

¹ <https://www.nrel.gov/docs/fy19osti/72847.pdf>

² <https://www.ashrae.org/aedg>

Shifting Costs

Rather than trying to sell clients on life cycle costs, seasoned ZE project teams break down costs to help owners understand how affordable a carefully designed ZE school can be. Here are few examples:

- As Kentucky's Warren County Public Schools learned, geothermal heating and cooling can be more expensive initially, but it is much cheaper and easier to maintain over the long term.
- Improving the building envelope can reduce the size and cost of the geothermal or other heating, ventilating, and air-conditioning (HVAC) system; for example, an investment of \$200,000 in Discovery Elementary School's envelope first costs allowed a savings of about \$500,000 in HVAC first costs.
- Rather than spend \$119,000 to upgrade all Discovery Elementary School's windows from double to triple panes, engineers calculated it would cost just \$9,000 to keep the double-pane windows and increase the size of the solar system while maintaining the building's ZE status.

Choosing a Procurement Process

The procurement process is the method used to purchase the goods and services required to design, construct, and operate a building. Most purchased items—appliances or tools, for example—are complete, discrete units and the design, engineering, and manufacturing costs are built into the price. Procuring a building, however, is a highly involved, customized process involving many players.

Procuring a ZE school on a conventional school budget requires an integrative design approach.³ This process considers each strategy, system, and component from the perspective of an overall ZE goal, namely achieving an EUI low enough that the building's energy needs can be met with an on-site renewable energy system.

There is no "perfect" procurement process, but the delivery method for a ZE school can be key to the success of a project. Design-bid-build, construction manager at risk, and design-build are examples of project delivery methods used to design and build schools.

Energy-related goals can be inserted into all three but incorporating energy goals is easier in some procurement processes than in others. For example, a performance-based design-build procurement process⁴ requires that the project team deliver a building that meets the energy and other performance-based goals for a firm fixed price. When the ZE goal and a firm budget are established early, the emphasis shifts from concerns about the cost of getting to ZE to determining how to achieve ZE within the budget. The project team is then free to explore creative approaches to energy and dollar savings that might be missed otherwise.

Regardless of the procurement process, contracts for designers and contractors should clearly describe energy and other performance criteria. The request for proposal should not prescribe solutions to avoid placing unnecessary constraints on the designers and contractors. A better strategy for owners is to let the professionals develop innovative solutions within the constraints of the budget.

When ZE becomes a school goal, selection of the design and construction team should be based on qualifications and best value. When the budget is fixed, all the bids will be the same and the choice will come down to which team delivers the best value within that budget.

For example, Arlington Public Schools used a design-bid-build process for Discovery Elementary School in Arlington, Virginia (see **Robust, Affordable K–12 Education: Arlington Public Schools**, page 28). Thanks to an innovative design team, the ZE bids were \$1 million less than the initial budget, making it possible to include a PV system to meet the ZE goal and still deliver the school for less than the original budget.

When the budget is not fixed in a design-bid-build procurement process, architects and engineers estimate construction costs during the design process and the building contractor does its own estimate based on historical cost data after the design is finalized. If the construction contractor's estimate is higher than the designers', the design is modified to meet the budget.

This can jeopardize the ZE goal, because equipment included in the design expressly to meet energy goals may have higher up-front costs than less energy-efficient choices. Switching the energy-efficient options for less

³ <https://www.nrel.gov/docs/fy19osti/72847.pdf>

⁴ <https://dbia.org/wp-content/uploads/2018/05/Primers-What-is-Design-Build.pdf>; <https://itd.idaho.gov/wp-content/uploads/Alternative-Project-Delivery-Workshop-2014-05-14.pdf>; <https://www.aceee.org/files/proceedings/2018/#/paper/event-data/p313>

energy-efficient options to meet the budget can ruin a building's chances of meeting its EUI targets, and, in turn, achieving ZE. School owners should be aware of these trade-offs and take steps to prevent energy efficiency compromises.

Hiring a construction manager committed to controlling costs and meeting the ZE goal is one such step. The construction manager's role is pivotal because subcontractors may not be familiar with ZE. Having an on-site ZE advocate monitoring progress and firmly rejecting changes that undermine the ZE goal can go a long way toward ensuring the success of the project.

A good design-build process also limits compromises because it defines all the rules in advance and determines the best value for the owner through a competitive process. This process can foster an environment that encourages open discussions about how to achieve the ZE goal and facilitate the process of identifying the team best qualified to successfully complete the project.

School district policies usually define permissible project delivery methods. Sometimes project teams can influence the decision, however, and team members committed to ZE goals may have strong opinions about process. One engineer put it bluntly, "If I could do every project using design-build delivery, I would."

Measuring and Verifying Performance

To ensure that the projected savings materialize, every ZE school should undergo a rigorous measurement and verification process.⁵ Some engineering firms pressure test every building. The envelope is critical to the sizing of the HVAC system, and a trend in ZE building cost control is to pay for additional envelope pressure testing, with the procedure outlined in the specification documents. By assuring envelope performance, the engineering team can downsize the HVAC to reflect the performance of the envelope that will actually be built.

The construction manager's role is pivotal because subcontractors may not be familiar with ZE.

As one engineer at a firm that guarantees building performance said, "If I know the envelope won't leak, I'm comfortable downsizing the HVAC system."

Acquiring a Solar System

The cost of PV has decreased dramatically, but some ZE schools are opting to enter into a power purchase agreement with a solar developer rather than purchasing the system outright. This arrangement has the advantage of not requiring additional capital for the PV system, and the district buys power from the solar developer at a lower price than the local utility rate. An additional advantage to the power purchase agreement model is that a private company can pass some of the tax benefit to the school, although that benefit will be decreasing in the coming years.

In some places, incentives are available that make purchasing PV attractive (see the Database of State Incentives for Renewables & Efficiency⁶ [DSIRE] for local incentives). For example, in Connecticut it makes sense to buy the PV system because the state will reimburse a significant percentage of the capital costs.

In locations where reimbursement is unavailable, however, private-party financing is an option because the financing party often qualifies for federal tax incentives. In addition, the incremental cost of adding PV to a commercial building has fallen to less than 3% of the project budget in many cases, considerably less than a typical 5% cost estimating error. This is because the cost of PV has plummeted during the last decade⁷ and more design teams are specifying PV and designing infrastructure to accommodate the installation. As PV becomes increasingly affordable, owners and construction professionals can include PV routinely in all commercial building budgets or—at a minimum—as an add-alternative (for more detail, see **Figure 5 on page 14** and the accompanying discussion).

School districts need to be cautious and educate themselves about solar pricing models, because utility demand charges or connection fees can impact the cost analysis. (DSIRE is an excellent source for local renewables and energy efficiency incentive programs. For more information on PV for ZE schools, see also the ZE K12 AEDG,⁸ pages 191–201). It is worth noting that energy efficiency is always a good investment for school districts.

⁵ <https://www.nrel.gov/docs/fy19osti/72847.pdf>

⁶ <https://www.dsireusa.org>

⁷ <https://www.nrel.gov/news/program/2021/documenting-a-decade-of-cost-declines-for-pv-systems.html>

⁸ <https://www.ashrae.org/aedg>



BENEFITS AND CHALLENGES

Jennings Creek Elementary School is part of an energy savings contract between Warren County Public Schools and CMTA Energy Solutions that guarantees the district annual savings of \$842,753 in utility and operational costs.

Photo from Sherman Carter Barnhart Architects, Chris Phebus Photography

Evidence is mounting that the perception that ZE schools cost more is a myth and ZE schools can be built on budgets comparable to or even smaller than conventional schools. They also use far less energy; the median U.S. K–12 school has an EUI of 48.5 kBtu/ft²·yr¹ and the target EUI of a new ZE school is usually less than half the national median. ZE schools are built using conventional materials, equipment, and tradespeople, and design, construction, and delivery processes have been refined to the point that a ZE school's performance can be guaranteed.

Benefits

The benefits of adopting ZE goals in K–12 schools are becoming better understood. Here is a summary of ZE school benefits for districts, students and staff, and communities drawn from existing ZE K–12 schools.

School Districts

Energy is often a school's largest expense after salaries, and over time, money saved on energy costs can be redirected to other priorities, including educational programs. The savings can be impressive.

The architect for Jennings Creek Elementary School (see **Small Decisions, Big Benefits: Warren County Public Schools, page 24**), for example, estimates that Jennings Creek saves nearly \$143,000 per year compared to a typical Kentucky elementary school. Including the revenue from selling solar-generated electricity back to the utility, the cumulative savings during the 20-year bond repayment period is expected to be nearly \$3.7 million.

ZE schools have lower operations and maintenance costs because wall, window, and roof systems are more durable than standard construction. Simpler and more accessible HVAC systems also reduce the cost of upkeep.

In addition, very energy-efficient buildings make it easier for district officials to accurately predict energy costs. Investing in energy efficiency and renewable energy also locks in today's energy prices, providing a hedge against future utility rate increases.

Students and Staff

ZE schools offer robust educational environments. They are living labs, with the building itself serving as a teaching tool. During design and construction, a ZE K–12 school focuses the school community (students,

teachers, staff, and parents) on the process of achieving ZE. Once the school opens, sustainability is typically built into curricula and many schools have formal energy clubs and other mechanisms to engage students and staff in operating the building (see **A Path to Energy Positive: Horry County Schools, page 30**). This exposure to science, technology, engineering, art, and math (STEAM) subjects can prepare students for future STEAM courses or careers.

ZE school occupants also report that their schools have exceptionally comfortable indoor environments. A new ZER school, Bluestone Elementary School in Harrisonburg, Virginia, was named the “Most Livable Building” in the United States by the University of California Berkeley's Center for the Built Environment. Now in its thirteenth year, the Livable Buildings Awards recognize projects that demonstrate high occupant satisfaction, excellent design, and innovative operation strategies.²

This achievement is particularly notable because, although excellent indoor air quality is critical to a “livable” building, it can increase energy use. The Bluestone project team achieved its energy goals *and* created a building with exemplary indoor air quality.

Communities

Reduced energy consumption reduces the school district's—and the community's—exposure to the risk of energy price volatility. Because the cost of designing and building a school with a low EUI is comparable to that of a conventional school, it can be an indicator that local officials are exercising sound fiscal management.

ZE and ZER schools are healthy, well-lit buildings and, as a result, they may be used more than conventional schools. More occupied hours can result in more energy use, and project teams should factor in use patterns as they design schools to achieve ZE or ZER status.

¹ <https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf>, page 2

² <https://www.vmdo.com/architecture-blog/bluestone-elementary-receives-livable-buildings-award/>

ZE schools can also improve local resilience. A K–12 school is often a community emergency shelter, and, because of energy-efficient design and daylighting, ZE schools can become safe and comfortable daytime refuges during extreme weather events and other grid outages. When battery storage is paired with the on-site renewables, a school can also maintain critical loads and comfort levels after the sun sets.

Challenges

Although many of the technical barriers related to designing and building a ZE school have been addressed, these projects still face challenges.

The data collected indicate ZE school costs are usually comparable to and can be less than conventional schools. Further, when costs are higher, it is often a result of aesthetic, comfort, or other upgrades rather than the building's ZE status.

Risk Management

During conversations and correspondence with educators and building professionals about ZE schools, the most-cited challenge by far was the perception that ZE schools are more expensive, and therefore risky, than conventional schools. The data collected for this publication indicate ZE school costs are usually comparable to and can be less than conventional schools. Further, when costs are higher, it is often a result of aesthetic, comfort, or other upgrades rather than the building's ZE status.

The perception of risk can become self-fulfilling. When a project team is unfamiliar with ZE building or unconvinced that such a facility can live up to the promise of its purported benefits, they are likely to increase their bids to account for unforeseen expenses.

A related issue is the difficulty of getting to ZE with business-as-usual approaches to design and construction. Architects and engineers interested in ZE will have to invest in developing the skills necessary to produce successful ZE schools.

In a perfect world, key stakeholders would be involved in the planning process from the beginning, would adopt and commit to the ZE goal, and would consider the ZE goal in each design and construction decision. The reality is likely to be that the ease with which a ZE school can be delivered will be unfamiliar to the project team at first and that existing procurement and delivery mechanisms may need to be modified to get to ZE. As more school districts and design and building professionals become enthusiastic about and comfortable with ZE, they will have to be patient and persistent as they educate their colleagues and communities.

If the design team is...not contractually obligated to meet a measurable, absolute EUI goal on a fixed budget, it could respond to cost increases and other challenges by arguing that ZE is not possible.

If the design team is unfamiliar with ZE and not contractually obligated to meet a measurable, absolute EUI goal on a fixed budget (see **Establishing a Budget and Energy Goal, page 17**), it could respond to cost increases and other challenges by arguing that ZE is not possible. Establishing an EUI goal and budget from the outset and choosing a design team with ZE experience or a willingness to learn the process can avoid these conversations.

School Governance and Funding

K–12 school-related decision making is local. Introducing a school district to ZE and ZER strategies involves outreach to a range of stakeholders, including school board members, administrators, members of the community, building professionals, and taxpayers.³ Any or all of these constituencies may be unaware or skeptical of the benefits of ZE.

Finding building professionals familiar with or willing to learn about ZE schools can also be a struggle, especially when building is booming. There is evidence that increased community interest in ZE is pushing design teams and construction professionals to take on these projects, however. Northeastern Connecticut, for example, now has two new ZE schools, largely as a result of public support.⁴

³ <https://www.nrel.gov/docs/fy19osti/72847.pdf>

⁴ <https://www.hartfordbusiness.com/article/net-zero-energy-schools-offer-ct-a-glimpse-of-future-green-development>



CASE STUDIES

The careful daylighting design at Discovery Elementary School in Arlington, Virginia, saves money on lighting energy while providing bright, inviting interior spaces.

Photo from VMDO Architects, Lincoln Barbour Photography



Richardsville Elementary, the first zero energy public school in the United States, operates at an EUI of 18.2 kBtu/ft²-yr, and produces more energy than it uses. Warren County Public Schools receives an annual refund from the electric utility of more than \$30,000 for the excess generation.

Photo from Sherman Carter Barnhart Architects, Joshua White, photographer

Small Decisions, Big Benefits: Warren County Public Schools

Warren County is Kentucky's fastest-growing county, and, in 2003, as part of an effort to serve its growing K–12 student population, Warren County Public Schools (WCPS) set a goal of saving \$3 million in energy costs in 8 years. The effort began with simple, no-cost energy efficiency strategies like turning lights off in unoccupied spaces. As existing schools were renovated and new schools were planned and built, the district adopted other cost-effective energy efficiency measures and soon exceeded its goal, saving more than \$4 million in less than 6 years.¹

As energy efficiency lessons were learned and applied to new and renovated schools, the process was steadily refined. When Plano Elementary School in Bowling Green opened in 2007, it was Kentucky's most energy-efficient school, operating at an EUI of 26.8 kBtu/ft²-yr. For context, at that time new conventional schools in Kentucky typically consumed 65 kBtu/ft²-yr.

Once Plano was operating, Mark Ryles, then facilities director for the Kentucky Department of Education, posed a question: "How would one design a net zero energy school and how much would it cost?"² That question launched an effort that involved engineers, architects, state regulators, utility companies, school board members, school facility managers, and school staff, and resulted in the design and construction of Richardsville Elementary, the first ZE school in the United States.

Being the first is risky, but the risk was mitigated somewhat by funding from the American Recovery and Reinvestment Act of 2009 (ARRA) that allowed Kentucky school districts to hire energy managers and included a \$1.36 million grant to WCPS that paid about half the cost of the PV system.³ Still, concerns persisted in some quarters.

"When Richardsville was in design, there was chatter about how much it was going to cost," said Kenny Stanfield, the project architect. "Zero energy was all theory at the time, so there was lots of pushback."

¹ <https://www.hpbmagazine.org/content/uploads/2020/04/09F-Plano-Elementary-School-Bowling-Green-KY.pdf>

² <https://www.hpbmagazine.org/content/uploads/2020/04/12F-Richardsville-Elementary-School-Richardsville-KY.pdf>

³ <https://livingbuilding.kendedafund.org/2017/04/11/net-zero-energy-schools-southeast/>; total cost of PV system was \$2.75 million, about \$7.90/watt

In addition, the project team faced a constraint unique to Kentucky—the Kentucky Department of Education mandates the maximum cost of every school in the state. (For example, in 2021, the maximum cost is \$262.70/ft² for elementary schools, \$265.78/ft² for middle schools, and \$274.69/ft² for high schools.⁴) To get to ZE, the school budget would have to include the cost of PV.

Energy modeling showed that a PV system large enough to offset the Plano EUI of 26.8 kBtu/ft²·yr would push Richardsville's cost beyond the state-mandated maximum, even with the ARRA monies. Clearly, the project team had to revisit the design, reduce the EUI, and cut costs.

"We had an advantage in that we'd done all the schools for Warren County and we had tracked the lessons learned," explained Stanfield. "On the Plano project—prompted by our facilities folks and engineers—we went with geothermal heating and cooling and improved the building envelope to achieve a low EUI."

Based on that experience, the district again used geothermal heating and cooling for Richardsville but chose insulating concrete forms (ICFs) for the exterior walls. ICF walls are well-insulated, contain thermal mass, reduce construction time, create a very tight building envelope, and resist winds of up to 250 mph. (Kentucky schools must be able to withstand 225 mph winds.)

Jennings Creek cost \$1.5 million less to build than the average Kentucky school and...saves more than \$195,000 a year in energy costs compared to a conventional school.

"Geothermal is more expensive initially, but much cheaper over the long term," said Mike Wilson, WCPS Facilities Director. "Districts have to decide between lowest first cost and the best long-term value for students and the community—for us, the choice was clear."

Once Plano was operating, its low energy use caught the attention of the utility, the Tennessee Valley Authority, which installed meters to monitor energy end uses in the building.

"We had never measured anything except total building consumption, but the utility's meters allowed us to look at all the end uses, which was very useful," said Stanfield.

The project team used the metered data to guide decision making. The result was that Richardsville Elementary School, the first ZE K–12 school in the United States, opened in 2010, came in on budget including the PV system, and has operated at an EUI of about 18 kBtu/ft²·yr ever since.⁵

WCPS' latest ZE school, Jennings Creek Elementary, opened in 2018 and demonstrates what is possible when a district commits to ZE. Jennings Creek cost \$1.5 million less to build than the average Kentucky school and had a design EUI of 17.5 kBtu/ft²·yr. The school is exceeding expectations—it operates at 15.5 kBtu/ft²·yr, and saves more than \$195,000 a year in energy costs compared to a conventional school.⁶

According to Stanfield, the bottom line is that "from our little corner of the world, cost isn't a barrier to ZE K–12 schools."

"From our little corner of the world, cost isn't a barrier to ZE K–12 schools."

— Kenny Stanfield, AIA, Sherman Carter Barnhart

⁴ <https://education.ky.gov/districts/fac/Pages/Property-Insurance.aspx>, "Property Insurance Replacement Costs 2021"

⁵ <https://www.hpbmagazine.org/content/uploads/2020/04/12F-Richardsville-Elementary-School-Richardsville-KY.pdf>

⁶ <https://www.scbarchitects.com/projects/jennings-creek-elementary/>

RICHARDSVILLE ELEMENTARY SCHOOL PROJECT DETAILS

Name Richardsville Elementary School

Location Richardsville, Kentucky
(9.3 miles north of Bowling Green, Kentucky)

Owner Warren County Public Schools

Building Type Elementary school;
includes gymnasium and cafeteria

Occupants 460 students and 35 staff

Floor Area 72,285 ft²

Distinctions/Awards

First ZE K–12 school in the United States

American School & University, Special Citation, 2008 and 2011

Andromeda Award, Alliance to Save Energy (Warren County Public Schools), 2009

Total Cost \$14,927,000 or \$206.50/ft²
[2010 dollars]

Photovoltaic System Cost
\$2.75 million

**Substantial Completion/
Occupancy** September 2010

**Average Operating Hours per
Week** 45

ENERGY DETAILS

Annual Site Energy Use Intensity
18.2 kBtu/ft²·yr

Electricity from Grid 18.2 kBtu/ft²·yr

**Annual On-Site Renewable Energy
Exported to Grid (from PV)**
17.8 kBtu/ft²·yr

Annual Net Energy Use Intensity
0.39 kBtu/ft²·yr

**Savings versus Standard 90.1-
2004 Reference Building** 52.8%

Photovoltaic system 348 kW

PROJECT TEAM

Building Owner/Representative
Warren County Public Schools,
Tim Murley, Superintendent

Architect Kenny Stanfield, AIA
Sherman Carter Barnhart

General Contractor
RG Anderson Company, Inc.

Mechanical Engineer
Mark Seibert, PE, LEED AP, CMTA, Inc.

**Electrical Engineer, Lighting
Design** Brian Baumgartle, PE, LC, LEED
AP, CMTA, Inc.

Energy Modeler Kosuke Kato, PE,
LEED AP, CMTA, Inc.

**Structural and Civil Engineer and
Landscape Architect**
Sherman Carter Barnhart

KEY ZERO ENERGY FEATURES

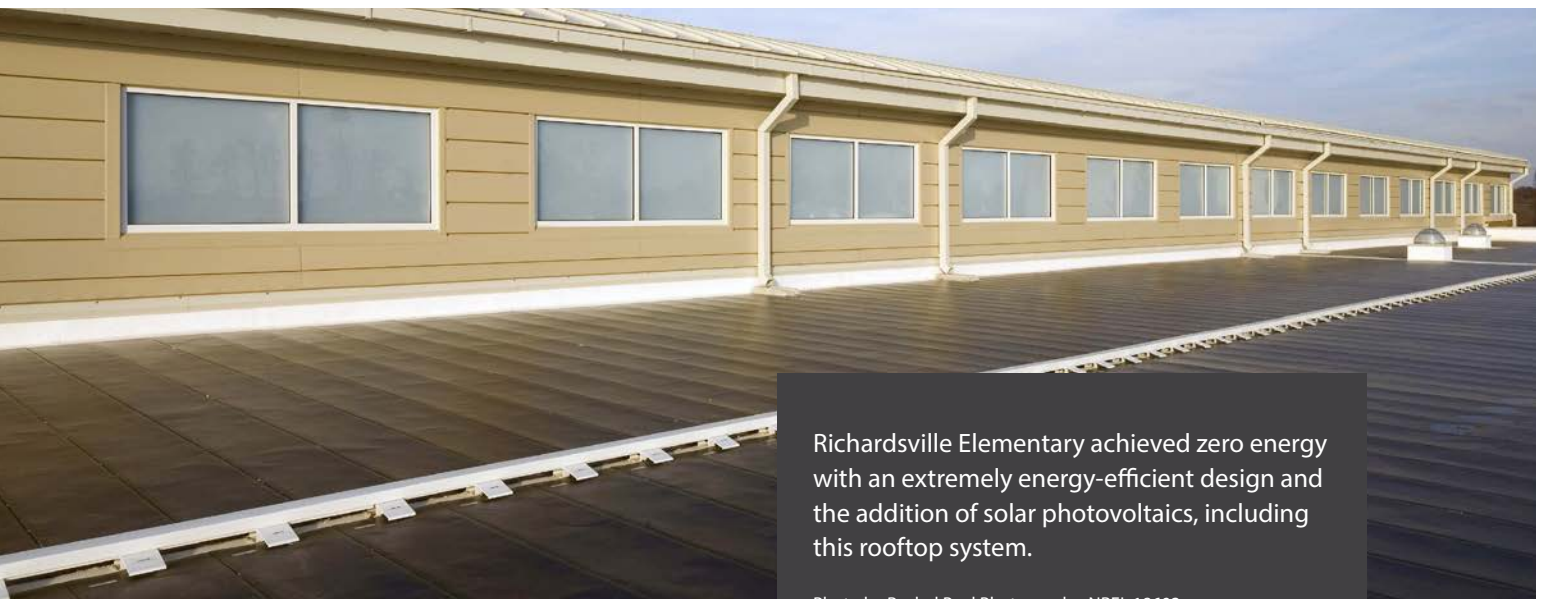
ICF building envelope

Solar photovoltaic system

Geothermal water source heat
pumps with a dedicated outdoor air
system

Daylight harvesting in classrooms,
corridors, and public spaces

Right-sized HVAC with the savings
used to enhance energy efficiency



Richardsville Elementary achieved zero energy with an extremely energy-efficient design and the addition of solar photovoltaics, including this rooftop system.

Photo by Rachel Paul Photography, NREL 18603

JENNINGS CREEK ELEMENTARY SCHOOL PROJECT DETAILS

Name

Jennings Creek Elementary School

Location Bowling Green, Kentucky

Owner Warren County Public Schools

Building Type Elementary school

Occupants 650 students

Floor Area 88,469 ft²

Distinctions/Awards

Total Cost \$18,400,000 or \$208 ft²

Substantial Completion/Occupancy
August 2018

ENERGY DETAILS

Annual Site Energy Use Intensity

Design EUI of 17.5 kBtu/ft²-yr; operating at 15.5 kBtu/ft²-yr

PROJECT TEAM

Building Owner/Representative

Chris McIntyre, Chief Financial Officer,
Warren County Public Schools

Architect Kenny Stanfield, AIA,
Sherman Carter Barnhart

General Contractor Alliance

Mechanical Engineer CMTA, Inc.

Energy Savings Performance

Contractor CMTA Energy Solutions

KEY ZERO ENERGY FEATURES

ICF building envelope

Superinsulated R-32 roof

350 kW solar photovoltaic system

Geothermal water source heat pumps
with a dedicated outdoor air system

Right-sized HVAC equipment and
use the savings to enhance energy
efficiency

LED lighting

Passive daylighting controls and
strategies

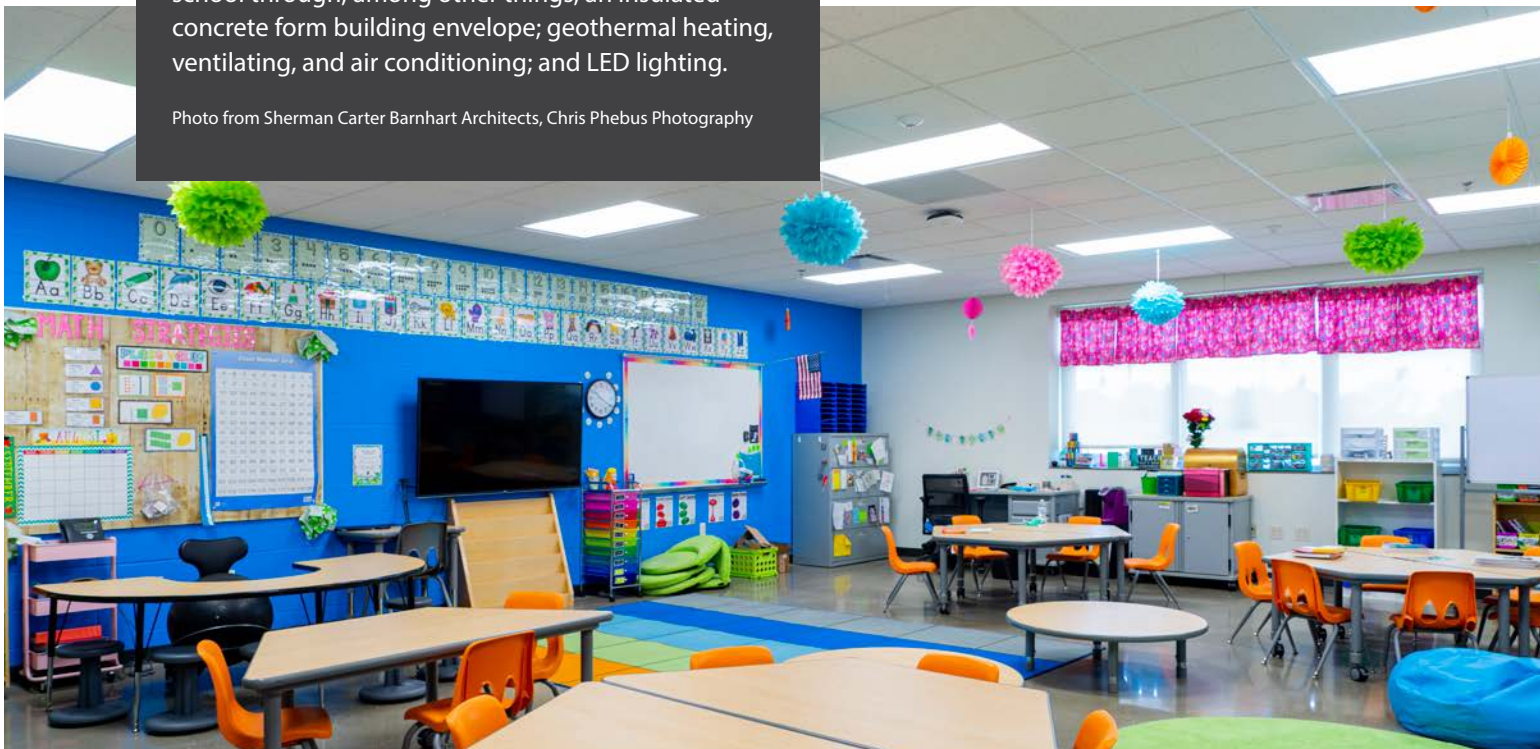
Geothermal HVAC

Efficient kitchen strategies—
eliminated type 1 hood

Occupancy, motion, and CO₂
monitoring

Jennings Creek Elementary School earned the distinction of being Kentucky's most energy-efficient school through, among other things, an insulated concrete form building envelope; geothermal heating, ventilating, and air conditioning; and LED lighting.

Photo from Sherman Carter Barnhart Architects, Chris Phebus Photography





Completed in 2015, the bids for Discovery Elementary School in Arlington, Virginia, came in at \$1 million less than the original budget, making it possible to add solar photovoltaics and achieve zero energy within the budget.

Photo from VMDO Architects, Digital Design & Imaging Service Inc.

Robust, Affordable K–12 Education: Arlington Public Schools

Like Warren County Public Schools in Kentucky, the Arlington [Virginia] Public Schools (APS) ZE journey was the result of many people making decisions that built on the work of others. APS wanted to create the best possible learning environments for students. Toward that end, the district looked into integrating environmental stewardship during the planning process for Discovery Elementary School and explored other school projects that could serve as models.

One they looked at was Manassas Park Elementary, an energy-efficient school in nearby Manassas, Virginia. Wyck Knox, principal at VMDO architects, had been the project architect and manager on that project. Impressed by its success, APS officials asked Knox to “give us one of those but make it better.”⁷

Knox hadn’t designed a ZE school, but he knew it was possible because it had been done at Richardsville Elementary in Bowling Green, Kentucky.

“Richardsville didn’t have a lavish budget, but it did have an innovative engineering team,” Knox said.

He realized the project would take his firm out of its comfort zone, energy performance would have to be

a central focus, and it would be important to measure building energy use regardless of where the data landed. Discovery’s budget was fixed and had been established to achieve LEED Silver®, but the project team examined the original budget and proposed a ZE school as a competitive advantage to win the job. Although they had not done a ZE design, by examining the practices of others and maintaining their determination to change how schools are designed, the team developed the successful ZE design.

School board members were intrigued but assumed the PV system required to get to ZE would break the budget. Still, they approved the project as a ZER building and decided to bid the solar system as an add-on.

When the ZE bids came back at \$1 million less than the initial budget, John Chadwick, APS Assistant Superintendent of Facilities and Operation, explained to district officials that even without the solar system, Discovery would be “the most energy-efficient building in the system.” Because the school was under budget even when the PV system was included, however, the board decided to make Discovery a ZE school.⁸

⁷ <https://www.nrel.gov/docs/fy17osti/68774.pdf>

⁸ <https://www.nrel.gov/docs/fy17osti/68774.pdf>

DISCOVERY ELEMENTARY SCHOOL PROJECT DETAILS⁹

Name Discovery Elementary School

Location Arlington, Virginia

Owner Arlington Public Schools

Building Type Elementary school

Occupants 630 students, 715 total

Floor Area 97,588 ft²

Distinctions/Awards

2017 AIA Committee on the Environment (COTE) "Top Ten" recipient, zero energy certification from the International Living Future Institute

Verified ZE building certified by the collaborative partnership of the International Living Future Institute and New Buildings Institute

Total Cost \$33,391,000 or 342.16/ft²

Project Budget \$36,000,000

**Substantial Completion/
Occupancy** September 2015

Delivery/Procurement Method
Design-bid-build

ENERGY DETAILS

Annual Site Energy Use Intensity
14.7 kBtu/ft²·yr

PROJECT TEAM

Building Owner/Representative
John Chadwick, Assistant Superintendent, Facilities and Operations, Arlington Public Schools

Architect Bob Moje, Principal-in-Charge; Wyck Knox, Project Architect

General Contractor
SIGAL Construction

**Mechanical, Lighting, Zero Energy
Design Engineer** CMTA, Inc.

**Power, Plumbing, Fire Protection
Engineer** 2rw Consultants

Structural Engineer Fox + Associates

Civil Engineer Bowman Consulting Group, Ltd

Landscape Architect Oculus

Traffic Toole Design Group

Construction Manager Heery International

KEY ZERO ENERGY FEATURES

Ground source heat pumps, dedicated outdoor air delivery, CO₂ sampling for controlling ventilation air, and energy recovery

ICF walls, high efficiency glazing, and exterior window shades

Energy-efficient laptops

Daylight switching zones with dimmable LED lighting

Dimming controls in classrooms and offices

Thermostats per heat pump zone

Roof-mounted photovoltaics

Type 2 cooking hoods and water-source refrigerators

Custom energy dashboard and educational solar lab

⁹ <https://www.nrel.gov/docs/fy17osti/68774.pdf>, <https://www.youtube.com/watch?v=2kTS4UODWwc>, <https://www.aia.org/showcases/71481-discovery-elementary-school-Name>



Discovery Elementary, a zero energy school in Arlington, Virginia, came in under budget even when the PV system was included, and provides a robust learning environment for students.

Photo from VMDO Architects, Lincoln Barbour Photography



A lesson learned from St. James Intermediate School and the other Horry County energy positive schools built from 2017–2018 is to research local utility rate structures and energy purchase and sales practices early in the process.

Photo from Horry County Schools

A Path to Energy Positive: Horry County Schools

Horry County Schools in South Carolina opened three new ZE schools in 2017 and two in 2018. The five schools, Ten Oaks Middle School, St. James Intermediate School, Socastee Elementary School, Myrtle Beach Middle School, and Socastee Middle School, are similar designs—two stories with an atrium, a hybrid geothermal system, daylighting, LED lights with control systems, a PV system on the roof, and a goal of producing 10% more energy than they use.

The district goal was an energy-efficient, high-performance school that generated more energy than it used and provided a collaborative learning environment. Achieving energy positive status involved reducing the energy demands of the building and installing PV to generate electricity that is used in the building as well as sold to the local utility. The school board used the same design-build team for all five projects to ensure consistency and replicability while maintaining the focus on achieving ZE. Horry County Schools learned valuable lessons during the design, construction, and operation of these schools.

Allow enough time to evaluate building performance. Horry County used a design-build procurement process that included a 3-year performance contract. The contract requires that the design-build team optimize the building's operation and demonstrate that the ZE goal has been achieved.

Contract directly with an independent commissioning agent and an independent firm that provides test and balance services early in the design process. When these professionals are at the table from the beginning of the project, there are opportunities to

review systems and identify small problems before they become big problems that can be time-consuming and expensive to correct.

Research local utility rate structures and buy/sell arrangements for distributed PV early in the design process. Once the building is using the least possible energy to operate—the new Horry County schools have design EUIs of 22 to 23 kBtu/ft²-yr—that energy must come from the on-site PV system to achieve ZE. In Horry County, however, the district buys electricity for \$0.17 to \$0.18/kWh and sells the PV output for \$0.03 to \$0.04/kWh. In addition, the utility only allows the schools to use 25% of the electricity the PV systems produce in the buildings and utility demand charges further erode energy savings.

Use submetering and other strategies to monitor how and when energy is used. Until energy storage is affordable and commonplace enough that it can be used to reduce demand charges, it is critical that building owners and operators know specifically how much energy the building is using and when that use occurs. This information can help operators reduce or avoid demand charges by shedding loads and shifting flexible and controllable loads to minimize their utility bills and optimize the solar resource when it is available. Most ZE buildings today do not have energy storage, which means a building would be more likely to achieve ZE or energy positive status in a regulatory environment in which the utility bought the output of the renewable energy system at or near retail rates and building operators could control demand charges with load shifting. If utility billing rate and usage issues are not understood and evaluated early in the design process, the building could meet or even exceed its energy goal but still not achieve its anticipated energy cost savings.

Engage students, teachers, and facilities staff in the operation of the building. Horry County is using staff support and on-site mentoring to form and maintain an EnergyWise (Wisdom Is Saving Energy and the Environment) club at each school. EnergyWise is a program developed by EDUCON Educational Consulting, Inc.¹⁰ The district is also using information and resources from the National Energy Education Development (NEED) Project,¹¹ including NEED energy science kits and the opportunity to participate in the Youth Achievement Awards

¹⁰ <https://educonenergy.com/about/>

¹¹ <https://www.need.org>

competition, to develop teacher curricula and support student energy clubs and other energy activities.

The new Horry County Schools came in at a 10% to 15% cost premium. According to Robbie Ferris, Firstfloor and SfL+A Architects CEO, however, the buildings were more expensive because “they include aesthetic upgrades, not because it costs more to get to ZE.”

ST. JAMES INTERMEDIATE SCHOOL PROJECT DETAILS

Name St. James Intermediate School

Location Myrtle Beach, South Carolina

Owner Horry County Schools

Building Type Intermediate school (grades 5–6)¹²

Occupants 870

Floor Area 170,918 ft²

DISTINCTIONS/AWARDS

American School & University, Educational Interiors August 2018 Issue, Outstanding Design, St. James Intermediate School

2018 ENR Southeast Best Project in the K–12 Education Category, Horry County Schools

South Carolina A4LE Excellence in School Building and Design Honor Award

Learning By Design, Grand Prize and Outstanding Project awards¹³

Total Cost \$47,700,000 or 279/ft²

Substantial Completion/Occupancy August 1, 2017

Delivery/Procurement Method Design-build

ENERGY DETAILS

Annual Site Energy Use Intensity
14.3 kBtu/ft²-yr

PROJECT TEAM

Building Owner/Representative
Rick Maxey, Ph.D. Superintendent,
Horry County Schools

Architect of Record
SfL+a Architects

Designer-Builder SfL+a Architects

Interiors Architect Stantec

Exterior Architect
Mozingo+Wallace Architects

KEY ZERO ENERGY FEATURES

Concrete stores latent heating or cooling energy

Centralized HVAC

Solar PV

LED lighting

Enhanced building automation

World class indoor air quality

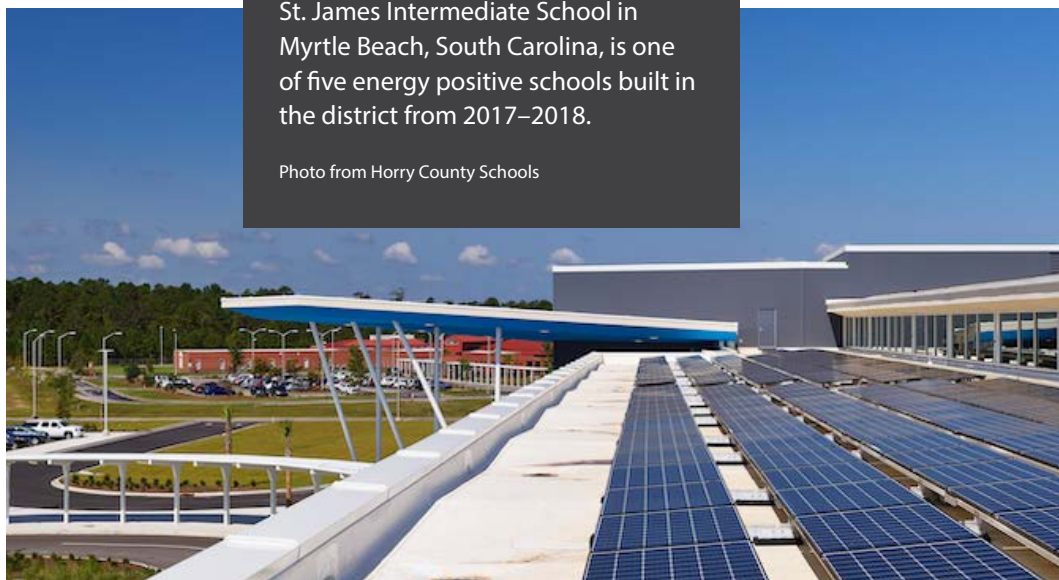
Superior building envelope

Monitoring-based commissioning

Advanced building analytics post construction

St. James Intermediate School in Myrtle Beach, South Carolina, is one of five energy positive schools built in the district from 2017–2018.

Photo from Horry County Schools



¹² <https://www.horrycountyschools.net/domain/3010>

¹³ <https://www.sfla.biz/two-horry-county-schools-honored-with-architectural-and-interior-design-awards/>



CONCLUSIONS

St. James Intermediate School in Myrtle Beach, South Carolina, which opened in August 2017, serves fifth and sixth graders and has a goal of producing 10% more energy than it uses.

Photo from Horry County Schools

The findings of this research indicate that pursuing ZE in K–12 schools does not have to increase design and construction costs and some ZE schools cost less than conventional schools.

Design teams that have achieved ZE have identified approaches that help avoid the challenges and optimize the benefits, notably:

- **Establishing a budget and energy goal early in the process** and considering the budget and ZE goal, expressed as an EUI, in every design decision, contract, and construction document; in short, make energy performance a major driver of the design and construction process
- **Shifting costs** by using integrative design to offset increased costs in one area (the building envelope, for example) with cost savings in others (the HVAC system, for example); the result can be reductions in both life cycle costs and first costs, a major focus for most school districts
- **Choosing procurement and construction management processes** that can get the project to ZE; although there are no perfect processes, a well-executed performance-based design-build strategy and a committed ZE construction manager can lock in a ZE goal and a fixed budget early in project development and provide cost control
- **Measuring and verifying performance** to ensure that the building operates at ZE during its lifetime; include input from measurement and verification professionals early in the project and design in approaches to educate students, replacement staff, and new teachers

about how the building operates and how everyone can be involved in maintaining its ZE status

- **Acquiring a PV system** to get to ZE can be complicated by utility demand charges, connection fees, and pricing for electricity fed back to the grid; districts can choose among a number of acquisition options, from power purchase agreements to owning the system outright.

Creating strategies for implementation is important to the success of ZE school projects. A checklist for success could create a preliminary framework for the routine design and delivery of ZE schools. Items on that list might include:

- Adding language to building procurement documents requiring a ZE goal; further, requiring that building energy use not exceed the recommendations in the ZE K12 AEDG¹
- Questioning potential project design teams about their track records creating buildings that achieved energy goals, especially a ZE goal
- Requiring that—at a minimum—a PV system be included as an add-alternate in any bid package.

St. James Intermediate School is one of five energy positive schools built from 2017–2018 in Horry County, South Carolina, that used a design-build procurement process.

Photo from Horry County Schools



¹ <https://www.ashrae.org/aedg>

ACRONYMS

EUI	energy use intensity
HVAC	heating, ventilating, and air conditioning
PV	solar photovoltaics
ZE	zero energy
ZE K12 AEDG	<i>Advanced Energy Design Guide for K–12 Buildings: Achieving Zero Energy</i>
ZER	zero energy ready

GLOSSARY

energy use intensity. The energy consumption of a building, expressed in thousands of British thermal units per square foot per year (kBtu/ft²·yr).

insulating concrete forms.¹ A building system, abbreviated as ICFs, that uses rigid foam insulation, steel reinforcement, and poured concrete to construct sturdy, continuously insulated walls.

integrated design.² A design strategy that considers each strategy, system, and component from the perspective of an overall energy consumption (EUI) goal low enough that the building's energy needs can be met with an on-site renewable energy system.

site energy use intensity. A building's energy consumption at the site.³

source energy use intensity. The total amount of raw fuel required to operate a building, including all transmission, delivery, and production losses.⁴

zero energy. A building with an energy use intensity (EUI) low enough that its energy needs can be met with an on-site renewable energy system, usually solar photovoltaics.

zero energy ready. A building with an energy use intensity (EUI) low enough that its energy needs could be met with an on-site renewable energy system and that has the infrastructure in place to support the renewable energy system, but whose owner has opted to delay the installation for budget or other reasons.

¹ <https://basic.pnnl.gov/resource-guides/insulated-concrete-forms-icfs>

² <https://www.nrel.gov/docs/fy19osti/72847.pdf>

³ https://www.energystar.gov/buildings/benchmark/understand_metrics/source_site_difference

⁴ https://www.energystar.gov/buildings/benchmark/understand_metrics/source_site_difference

APPENDIX A: ZERO ENERGY SCHOOLS ACCELERATOR

The Zero Energy Schools Accelerator,¹ launched by the U.S. Department of Energy in the fall of 2016, was a 3-year effort to identify, develop, and share strategies for achieving ZE in K–12 schools. Participants included 10 partner school districts, 3 states, and 11 nongovernmental organizations (see Zero Energy Schools Accelerator Participants for details). The National Renewable Energy Laboratory provided technical support.

ZERO ENERGY SCHOOLS ACCELERATOR PARTICIPANTS

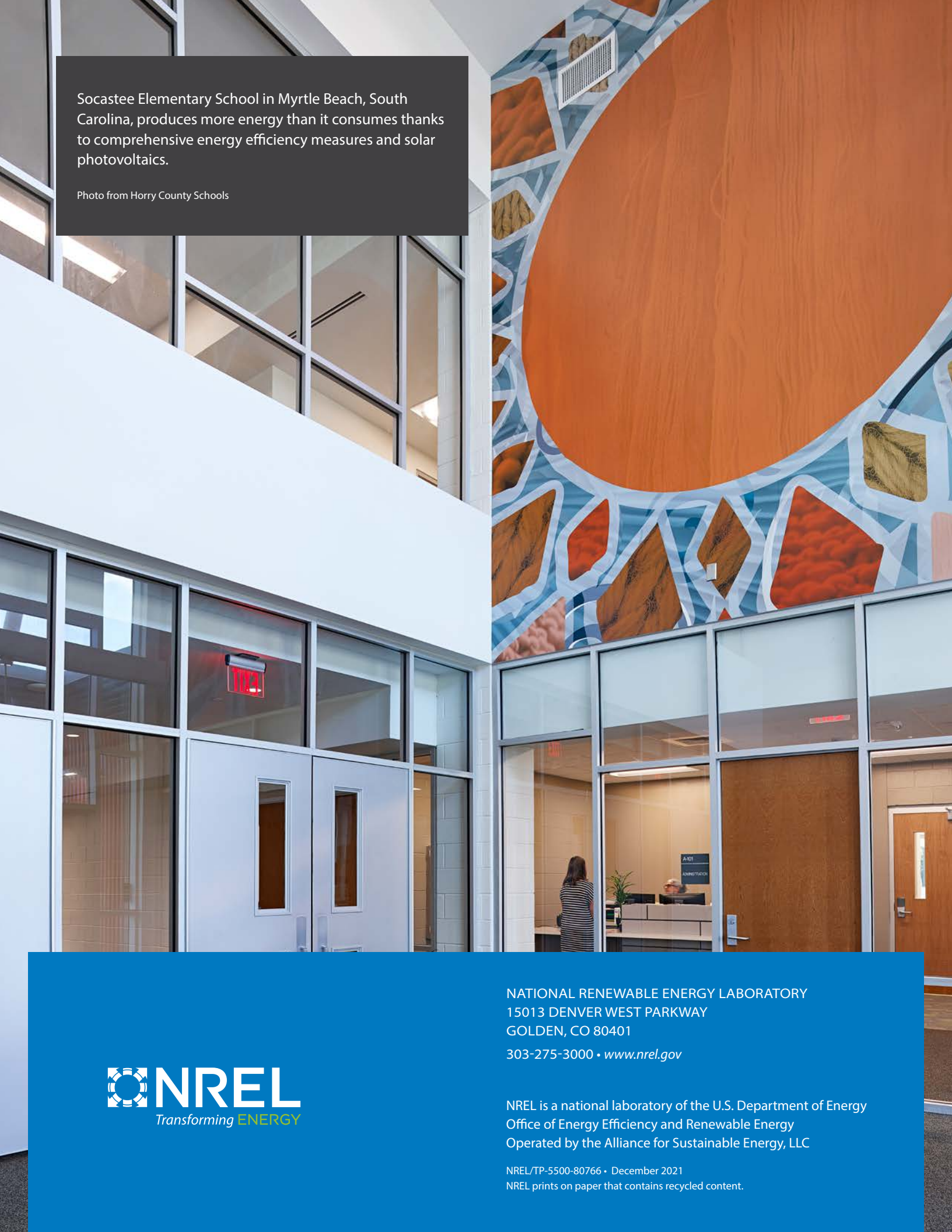
Implementing Partners

Adams 12 Five Star Schools (CO), **Shannon Oliver**
Alexandria City Public Schools (VA),
Azjargal Bartlett
Arlington Public Schools (VA), **John Chadwick & Cathy Lin**
Baltimore City Public Schools (MD),
Joanna Pi-Sunyer
Boulder Valley School District (CO), **Jeff Medwetz**
[State of] California, Department of General Services,
Division of the State Architect,
Chester Widom, Ida A. Clair
Douglas County School District (CO), **Wayne Blazek**
Hermosa Beach City School District (CA),
Nancy Bartolo
Horry County Schools (SC), **Mark Koll**
Los Angeles Unified School District (CA),
Christos Chrysiliou & team
[State of] Maryland, Maryland Energy
Administration, **Rory Spangler**
[State of] Minnesota, Department of Commerce,
Division of Energy Resources, **Lindsay Anderson**
San Francisco Unified School District (CA),
Nikolai Kaestner

National Partners

Association for Learning Environments (A4LE),
Donna Robinson
Collaborative for High Performance Schools (CHPS),
Elizabeth Krautscheid
Geothermal Heat Pump National and International
Initiative (Geo-NII), **Jack DiEnna**
National Association of State Energy Officials (NASEO),
Ed Carley
National Energy Education Development Project (The
NEED Project), **Karen Reagor**
New Buildings Institute (NBI),
Amy Cortese & Reilly Loveland
North East Energy Efficiency Partnerships (NEEP),
John Balfe & Carolyn Sarno
Rocky Mountain Institute (RMI),
Jacob Corvidae & Matthew Jungclaus
Southern California Edison (SCE),
Jerine Ahmed
The Energy Coalition (TEC), **Marc Costa**
U.S. Department of Education, **Andrea Falken**

¹ <https://betterbuildingssolutioncenter.energy.gov/accelerators/zero-energy-schools>



Socastee Elementary School in Myrtle Beach, South Carolina, produces more energy than it consumes thanks to comprehensive energy efficiency measures and solar photovoltaics.

Photo from Horry County Schools



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